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PROJECTING THE DEMAND FOR OHIO RIVER BASIN WATERWAY TRAFFIC USI--ETC(U)
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Summary Report

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Projecting The Demand For Ohio River Basin Waterway Traffic Using Correlation And Regression

JAN 1979

Ohio River Division
Cincinnati, Ohio
U. S. Army
Corps of Engineers

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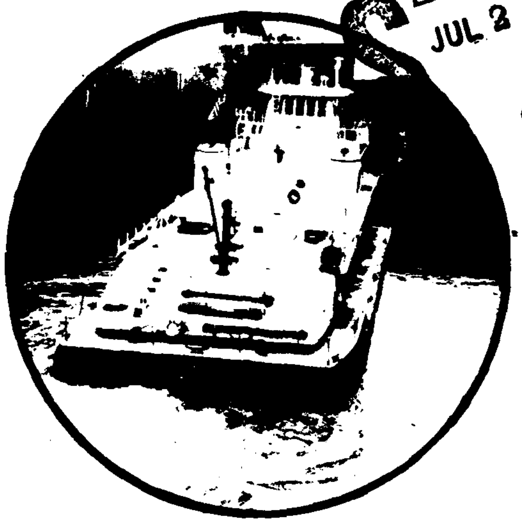

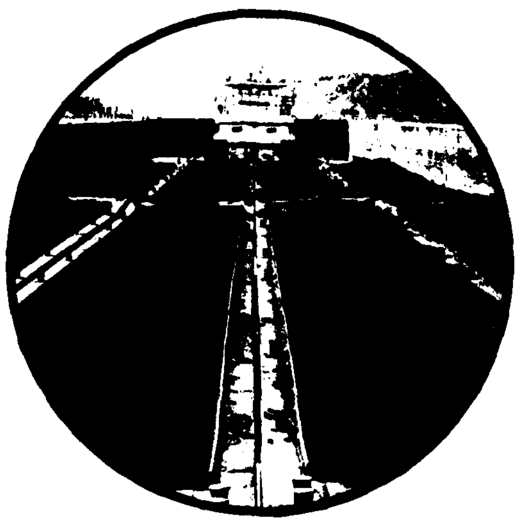

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This Corps of Engineers report describes one of three independent but complementary studies of future freight traffic on the Ohio River Basin Navigation System. Each of the studies considers existing waterborne commerce and develops a consistent set of projections of future traffic demands of all of the navigable waterways of the basin. Each report contains information on past and present waterborne commerce in the basin and projections by commodity group and origin-destination areas from 1975 to at least 1990.

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The three study projections, in conjunction with other analytical tools and system information, will be used to evaluate specific waterway improvements to meet short and long-term navigation needs. The output from these studies will serve as input to Corps' Inland Navigation Simulation Models to help analyze the performance and opportunities for improvement of the Ohio River Basin Navigation System. These data will be used in current studies relating to improvement of Gallipolis Locks, the Monongahela River, the Upper Ohio River, the Kanawha River, the Lower Ohio River, the Cumberland River and the Tennessee River, as well as other improvements.

This report and the 1975-1990 projected traffic demands discussed in it were developed by correlating the historic waterborne commodity flows on the Ohio River Navigation System with various indicators of regional and national demands for the commodities. The demand variable(s) which appeared to best describe the historic traffic pattern for each of the commodity groups was selected for projection purposes. The historic and projected values for the demand variables are based upon the 1972 OBERS Series E Projections of National and Regional Economic Activity. The OBERS projections were developed by the Bureau of Economic Analysis of the U.S. Department of Commerce in conjunction with the Economic Research Service of the Department of Agriculture.

Summary Report

PROJECTING THE DEMAND FOR OHIO RIVER BASIN WATERWAY TRAFFIC USING CORRELATION AND REGRESSION

DACW69-78-C-0018

Prepared for:

U.S. Army Corps of Engineers
Huntington District
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January 1979

PREFACE

This Corps of Engineers report describes one of three independent but complementary studies of future freight traffic on the Ohio River Basin Navigation System. Each of the studies considers existing waterborne commerce and develops a consistent set of projections of future traffic demands for all of the navigable waterways of the basin. Each report contains information on past and present waterborne commerce in the basin and projections by commodity group and origin-destination areas from 1975 to at least 1990.

The three projections, in conjunction with other analytical tools and system information, will be used to evaluate specific waterway improvements to meet short- and long-term navigation needs. The output from these studies will serve as input to Corps' Inland Navigation Simulation Models to help analyze the performance and opportunities for improvement of the Ohio River Basin Navigation System. These data will be used in current studies relating to improvement of Gallipolis Locks, the Monongahela River, the upper Ohio River, the Kanawha River, the lower Ohio River, the Cumberland River, and the Tennessee River, as well as other improvements.

This report, completed in January 1979, was prepared for the Corps by CONSAD Research Corporation of Pittsburgh, Pennsylvania. The study and the 1975-1990 projected traffic demands discussed in this report were developed by correlating the historic waterborne commodity flows on the Ohio River Navigation System with various indicators of regional and national demands for the commodities. The demand variable(s) which appeared to best describe the historic traffic pattern for each of the commodity groups was selected for projection purposes. The historic and projected values for the demand variables are based upon the 1972 OBERS Series E Projections of National and Regional Economic Activity. The OBERS projections were developed by the Bureau of Economic Analysis of the U. S. Department of Commerce in conjunction with the Economic Research Service of the Department of Agriculture.

A second report, completed in February 1979, was prepared for the Corps by Battelle Memorial Institute, Columbus, Ohio. The study and the 1975-1990 projections discussed in that report were developed by surveying all waterway users in the Ohio River Basin through a combined mail survey and

personal interview approach. Personal interviews were held with the major existing waterway shippers. The purpose of the shipper survey was to obtain an estimate from each individual shipper of his future commodity movements by specified origins and destinations, as well as other associated traffic information. The responses were then aggregated to yield projected traffic demands for the Ohio River Navigation System.

A third report, to be completed in September 1979 is being prepared for the Corps by Robert R. Nathan Associates, Inc. of Washington, D. C. The study and the 1975-2040 projections to be discussed in that report are much more comprehensive in scope, and focus on a much longer time frame. The basic study approach involves placing the historic production, consumption, and net shipments (by transportation mode) of commodities which move by water in the Ohio River basin into perspective with total national output. The production, consumption, and shipment estimates are being prepared for all geographic areas within the basin which are either directly or indirectly (through modal transfers) served by the Ohio River Navigation System. Economic, environmental and institutional factors which have historically affected output, consumption and modal shipments are being identified and analyzed. These same variables will then be projected through the year 2040 under alternative scenarios. Detailed waterway flow projections by commodity group and origin-destination areas will then be presented for the most probable future condition.

INTRODUCTION AND PURPOSE

In 1976 nearly 180 million tons of commerce was carried on the waters of the Ohio River navigation system. Most of this consisted of bulk-type commodities such as coal, sand, gravel, crushed rock, and petroleum fuels. These materials constitute major inputs to the basic industrial and energy production processes of the United States.

In order to insure the continued smooth flow of the above commodities, the U.S. Army Corps of Engineers must continue to maintain and improve the conditions of the rivers and navigation projects in the Ohio River Basin (ORB). Since funds for this purpose are limited, the Corps must develop a strategy for application of their financial resources so as to best achieve this goal.

As part of a systemwide study of commercial navigation in the ORB, the Huntington District of the U.S. Army Corps of Engineers has retained the services of CONSAD Research Corporation to project the demand for future ORB waterway traffic for the period 1975-1990.* The primary study area is defined to be the main stem Ohio River and all of its commercially navigable tributaries, including the Monongahela, Allegheny, Kanawha, Kentucky, Green, Cumberland and Tennessee Rivers. The elements of this analysis have consisted of the following:

TASK 1: Estimate future waterway traffic by commodity group (see Table 1) for the Ohio River Navigation System for the period 1975-1990 using correlation and regression techniques. The historic waterway traffic data to be used for this task were collected from Waterborne Commerce of the United States, Part 2.

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*This is only one of three ORB projection studies being undertaken by the Corps. The second study is based upon surveys of shippers and receivers, while the third study is examining a number of basic market conditions and trends.

Table 1: COMMODITY GROUPINGS TO BE UTILIZED FOR PROJECTING OHIO RIVER BASIN WATERWAY TRAFFIC

Commodity Group
1. Coal and Coke
2. Petroleum Fuels
3. Crude Petroleum
4. Aggregates
5. Grains
6. Chemical and Chemical Fertilizers
7. Ores and Minerals
8. Iron Ore and Iron and Steel
9. All Other

TASK 2: Using 1969-1975 PE to PE and BEA to BEA* flow data as provided by the Corps of Engineers, the forecasts from Task 1 were allocated to the BEA economic areas and river reaches within and outside of the Ohio River Basin, by commodity group. These future movements were then aggregated by direction to the main stem Ohio River, each navigable tributary, and through each of the seventy-one navigation projects in the Ohio River navigation system.

TASK 3: Separate, independent projections of waterway traffic by commodity group and direction of movement (upbound-downbound) were also generated for the main stem Ohio and each navigable tributary in an attempt to identify the degree of association between the behavior of the total Ohio River navigation system and its components. A similar analysis was also performed for traffic passing key navigation projects in the Ohio River System. These subsystem studies were intended to test the reliability of basinwide projections throughout the system.

This report summarizes the analytical techniques and results fully documented in the final report, "Projecting the Demand for Ohio River Basin Waterway Traffic Using Correlation and Regression."

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*PE stands for "port equivalent" and refers to a stretch of river possessing a composite of port characteristics. The term was defined as part of the Inland Navigation Systems Analysis program of the Corps of Engineers as an aid in water simulation projects. The term BEA as used in this report will refer to any of the 173 economic areas into which the Bureau of Economic Analysis has divided the United States.

DATA AND ANALYSIS

The data on the movements of commodities on the rivers under investigation were collected from Waterborne Commerce of the United States, Part 2, for the years 1953-1975. Prior to 1953, (back through 1940) this same information appeared in the Annual Report of the Chief of Engineers, Part 2, "Commercial Statistics."

This data was computer coded much in the same way as it appeared in the later volumes of Waterborne Commerce. That is, for each commodity, the directional distinctions of up river, down river, in river, out river, and through river (up and down) were retained to provide the maximum amount of flexibility in the data file. In addition, river and year codes were included.

In addition to the above data, CONSAD was provided with BEA to BEA and PE to PE movement data on all commodities for the years 1969-1976, and data on the 71 lock and dam projects by commodity group and direction as far back historically as existed.

Assuming that the patterns of past commodity flows bear some relationship to their future flows, and also assuming that these commodities are moving in response to the economic demands of the Nation, it is believed that quantitative relationships exist between economic indicators and waterway traffic levels. It is expected that these relationships could be determined from historical data using correlation and regression techniques and that these relationships could then appropriately be applied to future economic projections to obtain projections of future demand for waterway traffic.

In searching for economic indicators that could logically be considered as a driving force behind the movements of a particular commodity or commodity group on the waterways of the Ohio River Basin, it was found that compatability between annual historical data and the projected data was extremely rare. More specifically, we were able to locate numerous annual data series for all types of economic variables, but usually there were no projections in existence based upon the annual series. The projections that we were able to locate were not based upon historical data going as far back as 1940.

Finally, it was decided that our best source would be the Bureau of Economic Analysis in the U.S. Department of Commerce. The data tapes purchased from BEA included a 37-industry breakdown of earnings, total personal income, per capita income, and population. These categories were provided on an annual basis for the years 1965-1975 and included both national and BEA level data.

The above data sources are compatible with the OBERS Projection Series* prepared by the Bureau of Economic Analysis in conjunction with the Economic Reseach Service in the Department of Agriculture for the U.S. Water Resources Council. In addition to the projected earnings, income, etc., for the years 1980, 1985, and 1990, this series also provides observed historical data for the years 1950, 1959, and 1962. This brings the number of available historical observations up to fourteen.

Before any regression procedures could begin, the Waterborne Commerce data set had to be converted from the river specific format to a total system format that would take into account all traffic movements occurring on the rivers of the Ohio River Basin, for each commodity group. This was accomplished by summing the tonnages for all six directions on the Ohio River together with the tonnages for the two intra-river directions (up and down) for each of the seven tributaries. In this manner all ORB traffic was aggregated without any double counting.

After aggregation, a severe drop in curde petroleum shipments for the system as a whole was discovered. This decrease was found to correspond with the opening of a pipeline used for the transport of crude petroleum. Regression procedures were abandoned for this commodity group in favor of other means of determining future shipments (see Results and Conclusions Section for details).

The first step in the regression procedure for the other eight commodity groups was to develop a series of regression equations based on the historical data (dependent variable) and the OBERS economic series (independent variable(s)). The functional forms utilized were:

*1972 Series E OBERS Projections Series, Bureau of Economic Analysis, Department of Commerce.

1. Straight line: $Y = a + bX$

2. Second degree curve: $Y = a + bX + cX^2$

3. Geometric curve: $Y = a X^b$

4. Exponential curve: $Y = a b^X$

For each commodity group, several "specifically targeted" variables were chosen. By "specifically targeted" we mean those variables which possess some identifiable economic relationship to the commodities in a particular commodity group. Then, utilizing the SPSS* stepwise regression package to choose the variable or variables which has the greatest degree of explanatory power, a series of regression equations was developed. Both national level economic data as well as basin level data (created by aggregating data for the thirteen BEA areas which cover the ORB) were tested. In addition, a regression run was made using Gross National Product as the independent variable. The equations chosen for projection purposes and the resulting projections appear in the Results and Conclusions section.

At the subsystem level (individual rivers and key lock and dam projects) the same independent-dependent variable relationships tested at the system level for each commodity group were again tested on the system components. This analysis was undertaken primarily as a means of determining whether traffic on the system components is moving in response to the same demand variables and with similar correlations as is occurring at the system level.

In comparing the regression results obtained at the system level with those obtained at the individual river and key lock and dam levels of analysis, we find that when the same independent-dependent variable relationships are tested, a fairly strong degree of association exists between the system and its components. Based on this finding, it seems reasonable to utilize system level analysis, modified by local trends, to assign future traffic demand to the lock and dam projects in the ORB.

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*"Statistical Package for the Social Sciences", Norman H. Nie, C. Hadlai Hull, Jean G. Jenkins, Karin Steinbrenner, Dale H. Bent, McGraw-Hill Book Company, Second Edition, 1975.

Before deciding on a technique to be utilized in forecasting future port to port commodity movements, an inspection of the 1969-1976 origin-destination movements was made. This inspection showed that a great deal of stability existed in the patterns of O-D movements over this eight year period. Based on this finding, it was decided that the most appropriate technique for extrapolating the historic O-D movement trends to 1980, 1985, and 1990 O-D flows was to utilize Shift-Share analysis* in conjunction with the Fratar Growth-Factor method.** Both of these techniques are well suited for extrapolation purposes when no severe changes in historic patterns are anticipated.

Shift-Share analysis, given historic movement patterns and projections of future commodity group activity (described earlier), develops future shipping and receiving (O and D) totals for each commodity group and subarea (BEA or PE). These totals correspond to row and column sums of a commodity-specific O-D matrix. The Fratar technique constructs the future matrix cell entries according to a base year pattern adjusted by subareal growth factors.

After developing the 1980, 1985, and 1990 O-D matrix for each commodity group, the remaining task took these O-D flows and assigned the corresponding tonnages to the navigation projects along the river routes which would have to be traversed in going from an origin to a destination. This task falls under the general category of traffic assignment which may be broadly defined as the process of allocating a given set of trip interchanges to a specific transportation system.

The traffic assignment program included in the PLANPAC/BACKPAC*** computer package, although usually employed in modeling an urban transportation system, was easily adapted to our purposes. The river system under study can be thought of as a very simple road network, where PE's take the place of intersections ("nodes" in traffic assignment) and the navigation projects take the place of the roads connecting intersections ("links" in traffic assignment). Once the river network has been described to the computer, i.e., the location of all the PE's and navigation projects in relation to each other and all the distances involved, the computer constructs a minimum path tree for all O-D pairs.

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*Dunn, E.S., Jr., "A Statistical and Analytical Technique for Regional Analysis," Papers, Regional Science Association, 6 (1960), 97-112.

**Hutchinson, B.G., Principles of Urban Transport Systems Planning, Washington, D.C.: Scripta Book Company, 1974, pp. 84-85

***Computer Programs for Urban Transportation Planning, PLANPAC/BACKPAC General Information, April, 1977, U.S. Department of Transportation, Federal Highway Administration.

RESULTS AND CONCLUSIONS

The equations and associated projections presented in Tables 2 and 3 represent the results of the regression procedures described in the Data and Analysis section of this report. These projections were utilized in the Shift-Share procedure to provide a total tonnage figure for each commodity group specific O-D matrix in 1980, 1985, and 1990.

As was noted earlier, Commodity Group 3, crude petroleum, experienced a ten-fold decrease in tonnage between 1972 and 1974. This severe decrease corresponded to the opening of a pipeline between Owensboro and Catlettsburg, Kentucky. In order to ascertain the future picture of crude petroleum barging, an official of the Pipeline Division of the Ashland Oil Company was contacted and interviewed. The Ashland Oil Company is the major shipper of crude petroleum in the ORB area.

We were informed that within three years, all barging of crude petroleum on the rivers of the ORB would cease.* However, until such a time when a new pipeline could be constructed, or the capacity of an existing one increased, barging of crude petroleum from the Gulf coast up the Mississippi and eventually to Owensboro would continue at the approximate rate of 35,000 barrels/day. Given that a barrel of oil weighs about 300 lbs., the annual tonnage of crude petroleum would equal slightly less than two million tons. Therefore, although no further projections of crude petroleum shipments were undertaken, the 1980 upstream tonnages for all lock and dam projects on the Ohio River between Cairo and Owensboro reflect this estimated crude petroleum tonnage.

Table 3 presents the observed commodity group tonnages in five year increments between 1960 and 1975 and the projected tonnages for 1980, 1985, and 1990. Figure 1 displays the annual tonnages between 1960 and 1975 along with the projected values. As one can see, the demand for Coal and Coke, Petroleum Fuels, Aggregates, Chemicals and Chemical Fertilizers, and All Others is expected to approximately double. Tonnage of Ores and Minerals is expected to show the greatest percent increase while growth in Grain and Iron Ore and Iron and Steel is expected to lag behind the other commodity groups.

*The future intentions of other shippers will be ascertained during the other projection studies planned by the Corps for the ORB.

Table 2: EQUATIONS USED IN PROJECTING COMMODITY GROUP TONNAGES* AT THE SYSTEM LEVEL

Commodity Group		Equation
Tonnage of Coal and Coke	=	$-31,673 + 103\left\{\begin{array}{l}\text{Earnings in the}\\ \text{manufacutre of}\\ \text{Chemicals and}\\ \text{Allied Products}\end{array}\right\} - 29\left\{\begin{array}{l}\text{Earnings in the}\\ \text{manufacture of}\\ \text{Fabricated}\\ \text{Metals}\end{array}\right\}$
Tonnage of Petroleum Fuels	=	$-58,466 + 5.8\left\{\begin{array}{l}\text{Earnings in}\\ \text{Transportation}\\ \text{Communications}\\ \text{and Utilities}\end{array}\right\} + 3.4\left\{\begin{array}{l}\text{Basin Pop-}\\ \text{ulation}\end{array}\right\}$
Tonnage of Aggregates	=	$-4,284 + 8.8\left\{\text{Earnings in Contract Construction}\right\}$
Tonnage of Grains	=	$-16 + .8\left\{\begin{array}{l}\text{Earnings in Whole-}\\ \text{sale and Retail Trade}\end{array}\right\} - 2.7\left\{\begin{array}{l}\text{Earnings in}\\ \text{Agriculture}\end{array}\right\}$
Tonnage of Chemicals and Chemical Fertilizer	=	$-10,499 + 1.5\left\{\begin{array}{l}\text{Earnings in}\\ \text{Manufacturing}\end{array}\right\} - 2.1\left\{\begin{array}{l}\text{Earnings in}\\ \text{Agriculture}\end{array}\right\}$
Tonnage of Ores and Minerals	=	$-6,214 + 5.7\left\{\begin{array}{l}\text{Earnings in}\\ \text{manufacture of}\\ \text{Fabricated Metals}\end{array}\right\} + 1.5\left\{\begin{array}{l}\text{Earnings in}\\ \text{manufacture}\\ \text{of Primary}\\ \text{Metals}\end{array}\right\}$
Tonnage of Iron Ore and Iron and Steel	=	$-274 + 1.8\left\{\text{Earnings in Contract Construction}\right\}$
Tonnage of All Other Commodities	=	$-11,514 + 1.4\left\{\text{Earnings in Manufacturing}\right\}$

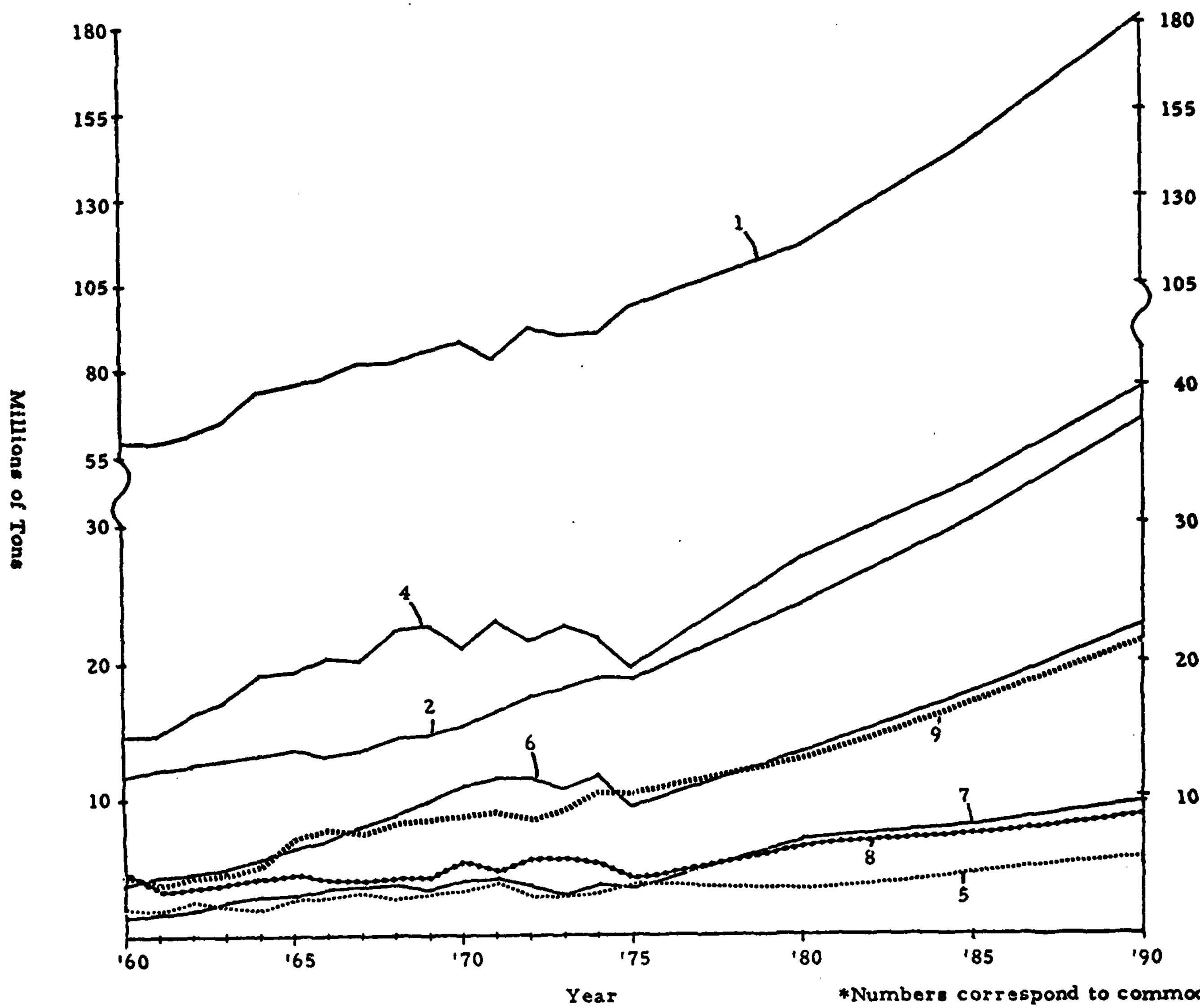
*These equations yield projections in thousands of tons. All variables represent basin level data.

Table 3: Observed and Projected Ohio River Basin Traffic by Commodity Group

Commodity Group	Observed*				Projected*		
	'60	'65	'70	'75	'80	'85	'90
1. Coal and Coke	59,724	75,369	88,246	98,237	117,031	146,605	182,256
2. Petroleum Fuels	11,597	13,680	15,544	18,846	24,312	30,565	37,663
4. Aggregates	14,441	19,642	21,144	19,666	27,845	33,296	39,727
5. Grains	2,016	2,546	3,373	4,097	3,354	4,317	5,456
6. Chemicals and Chemical Fertilizer	3,653	6,265	10,804	9,354	13,333	17,604	22,639
7. Ores and Minerals	1,294	2,824	3,916	3,446	6,294	7,890	9,739
8. Iron Ore and Iron Steel	4,524	4,367	5,194	4,162	6,244	7,350	8,655
9. All Other	4,479	7,297	8,592	10,316	13,041	17,090	21,854

*Thousands of tons.

Figure 1: Observed and Projected Ohio River Basin Traffic by Commodity Group*



*Numbers correspond to commodity groups in Table 3.

The methodologies employed by CONSAD in projecting future demand for waterway commodity flows have all utilized historic traffic patterns to predict the future trends. One should realize that changes in either the physical characteristics of the system (e.g., new and/or improved navigation projects) or the competitive relationship between water, rail and pipeline shipping rates, could cause significant changes in the tonnages of commodities moving on the waters of the Ohio River Basin.

In addition, the projected totals for each commodity group depended on the OBERS Series E projections for population, personal income, and earnings of certain key industries. If these projections turn out to be overly optimistic then the commodity group demand forecasts derived from them probably will not be reached.

Overall, the CONSAD analysis projects demand for future system traffic at a little under 328 million tons in 1990. This can be compared with just under 170 million tons of traffic moved in 1975. Table 4 presents total tonnage figures for five-year periods between 1945 and 1975, and the projected values for 1980, 1985, and 1990. Note that the average 5 year percent increase between 1945 and 1975 was 23 percent, quite comparable with the predicted 5 year percent increases between 1975 and 1990.

One might argue that the small increase in total tonnage between 1970 and 1975 represents a slowdown in the growth of waterborne commerce. However, the approximate 5 million ton increase between 1970 and 1975 includes a drop of over 6 million tons of crude petroleum shipments due to the opening of new pipelines. Thus, this special crude petroleum situation partially accounts for the small increase in total tons between 1970 and 1975.

It may well be that the recent apparent slowdown in the rate of increase of river traffic is due to the volume of river traffic approaching the capacity of the river system, i.e., the time required to ship by water may have increased due to the waiting times for use of lock facilities to the point where alternate modes of transport have become more competitive and thus more attractive. It should be noted that CONSAD has developed demand projections, and that capacity constraints were not used in any of this work except to the extent that historic volumes reflected such constraints. If the capacity of current facilities has been responsible for a slowdown in the rate of increase of waterborne commerce, and continues to be so, one would not expect river traffic to reach the levels estimated in this study without improvement of facilities.

Table 4: OHIO RIVER BASIN TOTAL TONNAGE*

Year	Total Tons	% Increase
1945	51,262	
		28.9
1950	66,092	
		54.6
1955	102,167	
		3.1
1960	105,318	
		29.7
1965	136,596	
		20.0
1970	163,903	
		3.1
1975	168,991	
		26.3
1980	213,454	
		24.0
1985	264,717**	
		23.9
1990	327,989**	

*Thousands of tons
**No crude petroleum

The assignment of commodity group tonnages to individual lock and dam projects was the result of systemwide projected commodity group totals being distributed among the individual originating and receiving ports according to the base year distribution modified by historical trends. This "system to component" approach seems reasonable in light of the analysis described in the Data and Analysis section where a fairly strong degree of association was discovered between the system and its components. However, this does not bely the fact that certain commodities are moving in response to very different and/or more localized variables than those that were tested in this study. It is expected that such issues will be addressed in companion ORB traffic projection efforts.